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field-effect transistor

Dictionary

field-ef·fect transistor (fēld'ĭ-fĕkt')
n. (*Abbr.* FET)

A transistor in which the output current is controlled by a variable electric field.

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Electronics

field effect transistor

(FET) A voltage controlled transistor in which the source to drain conduction is controlled by gate to source voltage.

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Wikipedia

Field effect transistor

The **field-effect transistor** (FET) is a transistor that relies on an electric field to control the shape of the

nonconductive depletion layer within a semiconductor material, thus controlling the conductivity of a "channel" in that material. FETs, like all transistors, can be thought of as voltage-controlled resistors.

Most FETs are made using conventional bulk semiconductor processing techniques, using the single-crystal semiconductor wafer as the active region, or channel. The channel region of TFTs (thin-film transistors), on the other hand, is a thin film that is deposited onto a substrate (often glass, since the primary application of TFTs is in liquid crystal displays). For more on TFTs, see thin-film transistor; the remainder of this article deals with the transistors most commonly used in integrated circuits. In biology, voltage-gated ion channels work in a similar way.

The terminals in FET are called *gate*, *drain* and *source*. (Compare these to the terminology used for BJTs: *base*, *collector* and *emitter*.) The voltage applied between the gate and source terminals opens and closes the conductive channel, modulating the resistance between source and drain.

FET Operation and "Pinch-off"

In Bipolar junction transistors the resistance of the conductive channel is determined by the thickness of the Emitter Depletion Layer through which charge carriers must pass. FETs are different; in FETs the insulating Depletion Zone is very thick, and it invades the conductive channel from the side, causing it to become narrow. An analogy with a light beam: if a BJT is like a dark filter of variable opacity which blocks the light, then FETs are like opaque irises which block the light by narrowing the aperature through which light must pass.

FETs have two modes of operation: variable resistance mode, and constant-current or "pinchoff" mode. When low voltages are applied to the Gate electrode and applied across Drain and Source, the Depletion Zone surrounding the Gate is small, leading to a wide conductive channel between Source and Drain connections. As the Gate reverse voltage is increased and the Depletion Zone grows, the conductive channel becomes proportionally narrower and the channels resistance increases. This describes the variable-resistance zone, since any changes in Source-Drain voltage will have little effect on the shape of the Depletion Zone and little effect on the channel resistance. Changes in Source-Drain voltage produce proportional changes in current, and on the whole, the channel acts like a resistor.

As the Gate voltage is increased further, the Depletion Zone enlarges and closes off the channel. However, the charge flow within the channel does not drop to zero. Instead a complicated negative-feedback mechanism begins to operate. Because the Source/Drain voltage is distributed lengthwise along the resistive channel, the potential difference between each position along the channel relative to the Gate electrode is not the same. This causes distortion in the shape of the insulating Depletion Zone. When the Gate voltage is so large that the Depletion Zone attempts to close the channel entirely, instead the Source/Drain voltage becomes concentrated where the channel begins to close, and avalance breakdown begins. This holds the channel open. Because of this effect, the channel cannot shrink below a certain small width, although any increases in the size of the Depletion Zone will cause the remaining narrow passage to grow longer. And most important of all: if the Source-Drain supply voltage is set to a higher value, the Depletion Zone will increase in size, the conductive channel will become longer rather than narrower, and the channel resistance will increase with increasing voltage. Because resistance increases with applied Source-Drain voltage, the flow of charge through the channel will remain relatively constant. The channel has become a kind of "constant current resistor," a resistor with a very high Ohms value yet with a significant current. This current can be controlled via the Gate voltage, yet is relatively immune to changes in the Source-Drain voltage. This describes the so-called "Pinch-off mode" or "constant current mode."

Pinch-off is the usual operating mode for FETs in linear amplifier applications. Variable-resistor mode

depends on low Source-Drain voltages, while Pinchoff mode does not. Note that "Pinch-off" does not mean "pinched-closed."

Types of field-effect transistors

The FET is simpler in concept than the bipolar transistor and can be constructed from a wide range of materials. The different types of field-effect transistors can be distinguished by the type of insuation between channel and gate:

- The MOSFET (Metal-Oxide-Semiconductor Field-Effect Transistor) utilizes an insulator (typically SiO_2).
  - Power MOSFETs become less conductive with increasing temperature and can therefore be thought of as n-channel devices by default. Silicon devices that use electrons, rather than holes, as the majority carriers are slightly faster and can carry more current than their P-type counterparts. The same is true in GaAs devices.
  - Power MOSFETs are typically Vertical-FETs, where the active device is built along the rims of hexagonal pits in the semiconductor surface, and the Drain current flows vertically down the surface of the pits.
- The JFET (Junction Field-Effect Transistor) uses a p-n junction to produce the depletion layer.
- Substituting the p-n-junction with a Schottky barrier gives a MESFET (Metal-Semiconductor Field-Effect Transistor), used for GaAs and other III-V semiconductor materials.
- Using bandgap engineering in a ternary semiconductor like AlGaAs gives a HEMT (High Electron Mobility Transistor), also named an HFET (heterostructure FET). The fully depleted wide-band-gap material forms the isolation.
- The distinguishing feature of the TFT (thin-film transistor) is the use of amorphous silicon or polycrystalline silicon as the channel.

Uses

The most common use of MOSFET transistors today is the CMOS (complementary metallic oxide semiconductor) integrated circuit which is the basis for most digital electronic devices. These use a totem-pole arrangement where one transistor (either the pull-up or the pull-down) is on while the other is off. Hence, there is no DC drain, except during the transition from one state to the other, which is very short. As mentioned, the gates are capacitive, and the charging and discharging of the gates each time a transistor switches states is the primary cause of power drain.

The C in CMOS stands for 'complementary.' The pull-up is a P-channel device (using holes for the mobile carrier of charge) and the pull-down is N-channel (electron carriers). This allows busing of the control terminals, but limits the speed of the circuit to that of the slower P device (in silicon devices). The bipolar solutions to push-pull include 'cascode' using a current source for the load. Circuits that utilize both unipolar and bipolar transistors are called Bi-Fet. A recent development is called 'vertical P.' Formerly, BiFet chip users had to settle for relatively poor (horizontal) P-type FET devices. This is no longer the case and allows for quieter and faster analog circuits.

A clever variant of the FET is the dual-gate device. This allows for two opportunities to turn the device *off*, as opposed to the dual-base (bipolar) transistor which presents two opportunities to turn the device *on*.

FETs can switch signals of either polarity, if their amplitude is significantly less than the gate swing, as the devices (especially the parasitic diode-free DFET) are basically symmetrical. This means that FETs

are the most suitable type for analog multiplexing. With this concept, one can construct a solid-state mixing board, for example.

The power MOSFET has a 'parasitic diode' (back-biased) normally shunting the conduction channel that has half the current capacity of the conduction channel. Sometimes this is useful in driving dual-coil magnetic circuits (for spike protection), but in other cases it causes problems.

The high impedance of the FET gate makes it rather vulnerable to electrostatic damage, though this is not usually a problem after the device has been installed.

A more recent device for power control is the insulated-gate bipolar transistor, or IGBT. This has a control structure akin to a MOSFET coupled with a bipolar-like main conduction channel. These have become quite popular.

External links

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